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CHARACTERISTICS OF THE AUTHENTICITY AND SUSTAINABILITY IN THE PRESERVATION OF TUFF MASONRY

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ABSTRACT

In this paper, the reasons for the continuity of the traditional masonry methods are analysed as well as the characteristics of the preservation of the historical heritage built with volcanic tuff in Arequipa (city located in South America, SW of Perú). This study analyses the sustainability and authenticity of the monumental restoration in which an antiseismic rehabilitation of masonry and vaulted surfaces has taken place.

INTRODUCTION

The construction using this material, tuff, has been maintained throughout since the times when the new city of Arequipa was founded in 1540 during the Spanish colonisation. Due to the importance of historical, constructive and artistic values of the historical centre (74 Ha), a declaration as patrimony of humankind has been drawn up on the UNESCO.

Another point to consider is that, the Spanish technology transference of stone masonry was possible due to the abundant material existing there and to the lack of forests in that area. The massive construction of double leaf walls and barrel vaults to cover not only great spans but also small ones was significant in civil, residential and religious works giving rise to the mixed baroque style of Arequipa with its singular carved façades (Fig. 1 Casa del Moral s XVIII).

1. Continuity of the traditional masonry

The continuity of use of this material is based on three basic interrelated aspects which are: the existence of local quarries within the urban perimeter of the city, the persistent use of this material over four centuries and the need to preserve the monumental heritage which constitutes the most representative values of the local culture.

Figure 1.

a) Quarries in use

The material known as work stone refers to the physical characteristics of the cut material and not to its geological origin or to its chemical composition. Made of compact volcanic tuff, it includes fragments of quartz, feldspar and andesite. Its hardness being 4 in Mohs scale permits an easy cutting to be used as a cladding material or as ornamental engraving. Its compressive strength is 8 Mpa, and its tensile strength 0.5 Mpa (1) (true density 2.36 gr/cm^3, absorption coefficient 32.64%, and open porosity 41.41%).

The most exploited quarry produces a white material (Fig. 2), but it also exists in pink and yellow colour. This quarry has a length of 18km, in a canyon surrounded by walls on both sides and a depth of 60m in its deepest side. Presently 120 stonemasons work there autonomously earning according to their work. The exploitation of the mine is done in the open, using tools such as hammers, bars, ringers, picks, spalling wedges, chisels etc. Although there is a restricted production of pieces tailored singularly for the specific restoration works, for popular architecture the stonemasons rough-hew the stones using the palm as measuring unit, obtaining quite uneven pieces. The pieces of 60cmx30cmx20cm are really 57cmx31cmx19cm corresponding to a greater palm of 19 cm, and to a smaller palm of 12 cm (equivalent to 3 x 1 greater palm + 1 smaller palm x 1) (2).

b) Continuity of the use of tuff

During the Spanish Viceroyalty, this material was used in double leaf walls with stone filling, called "cal y canto". It was used in lintels, cornices, barrel vaults, façades,

Figure 2.

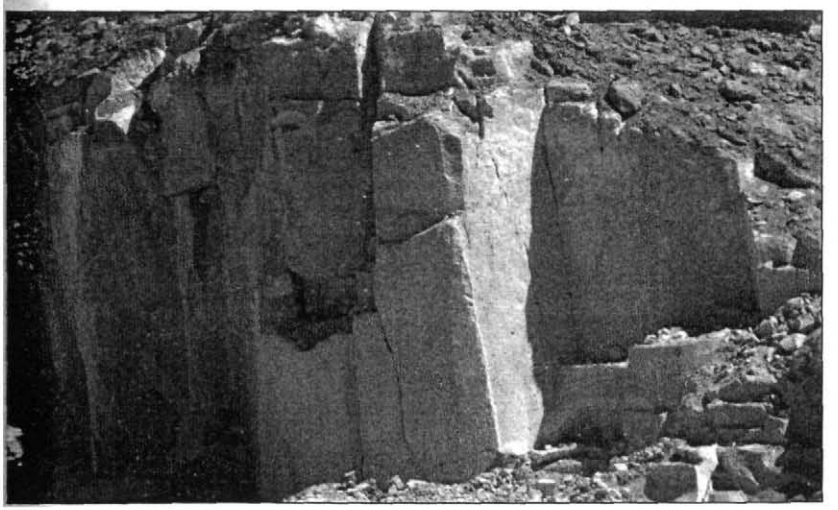
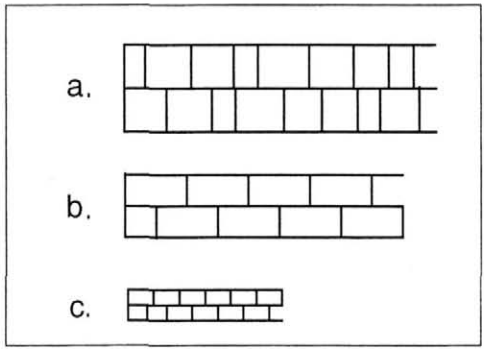


Figure 3.



courtyard floors, drainage channels. That is, it was the sole material used for both structure and finishes, not considering bricks and tiles. The work stones had the dimensions derived from the Spanish stick, 40cmx40cmx20cm (1/2x1/2x1/4 stick), in such a way that two of them were placed at the quoins standing on the thicker side separated by a work stone placed in a rowlock position. This determined sections of 1m or more, if they were wider. In the stone bonds two or three work stones were separated with one in a rowlock position. Later in the 19th century, the sections of the wall were reduced constructing them only in heading bonds with flat slabs. In the second half of the 20th century, due to the influence of bricks more resistant to earthquakes and to the smaller space occupied by them, the work stones began to be cut into 40cmx30cmx20cm until reaching the 60cmx30cmx20cm of present times. This size can be easily adapted to the stretching and heading bond wall construction. But by starting to cut pieces with machines and wet, the stonemasons were able to produce 15cmx25cmx2cm pieces used for wall claddings, all in the same colour or combining white and pink (Fig. 3, a. Colonial bond, b. Contemporary bond, c. Wall cladding with "sillar arequipeño").

c) Conservation of the architectural heritage

The need to preserve the historical heritage of the city produced the interest of particular and institutional interventions in the restoration and rehabilitation of the main historical buildings. Although a great amount of the religious buildings have been maintained, many examples of minor architecture have been lost, not only due to man intervention, but also due to natural forces (Fig. 4). The 1868 earthquake and the subsequent ones of 1958 and 1960 originated two great phases in the reconstruction of the city as well as main technological changes. In the first period, the tuff vaults were changed to flat roofs with double T metal beams and cap vaults also made of stone, which facilitated the rise in height in one or two levels. Meanwhile in the second period, several consolidations were performed to increase the resistance to earthquakes. At the same time a period of revaluation of the existing heritage started.

2. Justification of the apparent authenticity

Even if maintaining the authenticity of the work of art implies the conservation of the three acts concerning its production –the creation, the time action and men's action– in the architectural work the constructive technology is contemporaneous to the first action, and therefore to the last one, to the process of restoration specifically speaking and considered to be the authentic third act (3). Nevertheless, in the interventions performed, these acts do not appear as clearly as they are theoretically described, therefore the authenticity is identified with the respect of formal values even if not all the materials are original.

a) Antiseismic rehabilitation

The settlement of a historic heritage in a seismic area originated the strengthening of masonry inserting reinforced concrete structures. Even if these interventions do not alter visually the work of art, in strict sense, they are practically irreversible and therefore, we are in the presence of a third act which modifies the creation. This may be totally justified because it lengthens the life of the buildings.

Obviously, the insertion of framed structures has transformed the mechanical behaviour of the old stonework, but it has been an option to increase the user's security and the resistance to the continuous earthquakes. The use of beams acting as tie beams in the headwalls has been a normal practice, as well as installing corrugated iron rafters for bracing the load bearing walls, casting columns in the

Figure 4.

work stone corners, placing sheaths (Fig. 5 finished roof brick tiles) and ribbed arches in the extrados of the barrel vaults and domes, and introducing lintels and other small interventions in mass concrete.

b) Masonry changes

Apart from the different actions to reinforce the structures, the adaptations to new uses and the need to increase the expensive land profitability in the historical centre as well as the modernisation of the buildings, demand several changes. These changes mainly alter the original section of the double leaf walls, be them closure walls or partitions even though they might have the same thickness.

In closure walls, new spans, windows or doors with straight or curved lintels are introduced. Also the conversion of windows into doors by the elimination of the splay can take place, including a couple of stairs steps in case when the street level is different from that of the interior taking advantage of the wide quoins. The building division and the adaptation of the old houses into commercial premises have transformed the image of the façades. The façade, consisting of an entrance door with grille windows on both sides was changed into several doors of different dimensions. This action which although altering the façade, is a minor evil when compared with the irreversible demolition of the building to obtain a greater number of commercial premises. Another change in the colonial façades is the maintenance of the foyer, and therefore of the courtyard which had remained concealed from the street, open and used as commercial gallery in some occasions allowing the entrance of the public by keeping the wooden doors open.

Figure 5.

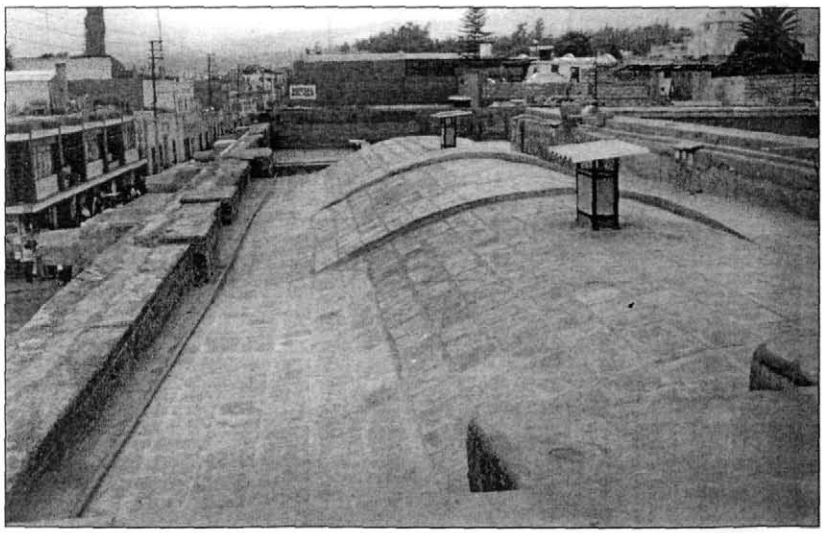


Figure 6.

In the partition walls good use has been made of the existing storing spaces and of the niches of arches of the kitchen chimneys to introduce the toilets in both houses and commercial premises. In cases where these spaces were not available new openings not higher than 2m, have been introduced eliminating one leaf of work stone as well as the stone and mortar filling.

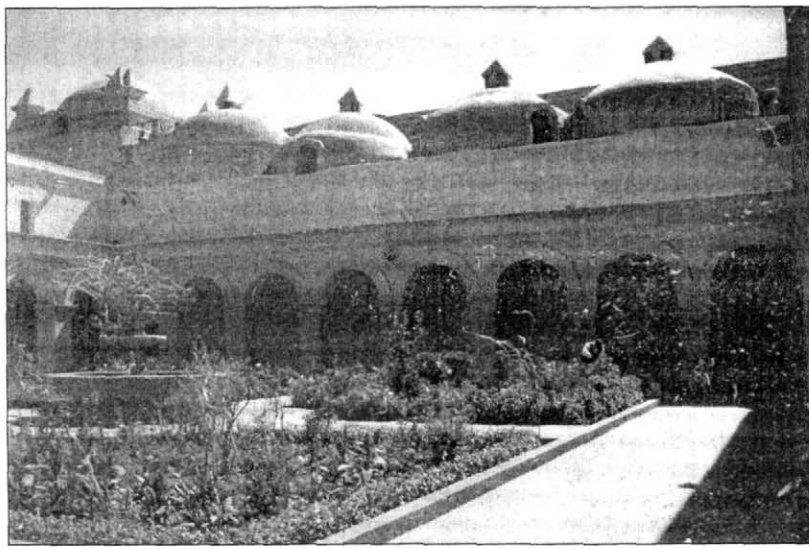
In order to increase the light, there has been no other alternative than to broaden the spans or to open them where they were necessary. In order to increase the occupation density, the height of the room has been divided with a slab which spreads to one of the headwalls only creating new windows when possible (Fig. 6). In one-storey houses, it has been necessary to eliminate one of the headstones of the vaults to ensure zenithal light.

One could say that the walls loose their authenticity increasingly in the elevations, although not in the sections and lay out. They can be recognised in the foundations since no basements are introduced; therefore it allows the substructure to stay untouched in contrast with the new interventions performed in these strata.

c) Material seen or painted

Colour is an inherent quality to conserving the authenticity and there is no discussion to it, except for the fact that the whiteness of the material is attractive for experts and non-experts. The convent of Santa Catalina is considered the most important monument in relation to its evolution and to the technological chan-

Figure 7.



ges that its growth implied from the 16th century until its consolidation in the 18th century. Later in 1970 when the interventionist maintenance and preservation for the visit of tourists concluded, the monastery showed the colours indigo, red ochre and yellow with which the walls were originally painted.

Nevertheless, outside the monastery, an excessive cleaning was performed which spread to the church aisles eliminating all the painting and decoration, showing the whiteness of the stone barely altered by black or brown andesite inlays (Fig. 7 Monastery La Merced). From 1972, the historical zone was delimited with the most important monuments to be conserved, and in the 80's, local codes were established which imposed the whitening of the city. This ignited the discussion between the colour recuperation or the perception of the work stones without coating, painting or rendering. The duality would be maintained because both are inherent to the evolution and use of this material, although the claddings alleviate the constant powder expulsion and delay the stone erosion in an atmosphere polluted by the public transport.

3. Difficulties to distinguish the new work

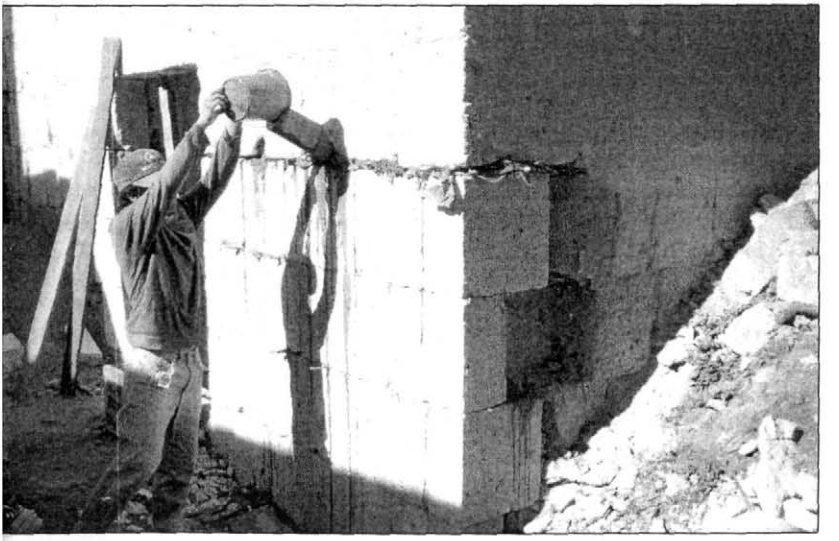
Due to the new technologies and the documentation of the monument available the mimesis of old and new is such that it is possible to reconstruct in a reliable way the lost part with the same materials and traditional masonry techniques. It is not necessary to use materials of similar characteristics or specialised personnel, as it is needed in the restoration of artistic elements of churches, altarpieces, glass

windows or organs. This requires the study the work stones, the metrology or the chemical analysis of mortars to date the construction.

The difficulties to express the physical and visual differences between new and old works, lay more than in the use of the stone itself, in the fact that very seldom a crust or patina is formed. Normally the stone masonry lack a final treatment or finishing coat to even the surfaces since it does not need them, particularly in the restorations in which one can distinguish the third act. The stonemason polishes the seen surfaces with another harder stone finishing his work with it. The levelling off between the old and the new stones is almost immediate after cleaning the dirtiness with a brush, or washing it with a water jet which makes the material yellowish, ageing it.

In the masonry restoration the difference is produced in the composition of the mortar joints: more lime in the old stones and Portland cement in the new ones. The work stones changed are cut to the same original dimensions, squared. There are also rectangular ones, although it had no sense to have three dimensions if all the pieces were standing by the header, except in great public buildings. Some of the work stones are placed with no mortar and others are placed forming joints filled with mortar poured with a nozzle (Fig. 8). In the internal side of the wall the joints are filled with mortar 1:4 (lime + aggregate) without reaching the exterior, so that equalising mortar can be applied. The composition of this equalising mortar is $^{1}/_{4}$:2:4 (cement + lime + stone dust). This fine stone powder obtained by pulverising the stone, affects the levelling of the external aspect of the stone masonry and is the base on which to apply the paint or lime. The problem is that it eliminates the rounded edges eroded by the time, eliminating at the same time the action of time.

Figure 8.



The walls of the popular buildings, a great many of them made by their proprietors, are built with work stones with contemporary dimensions. Therefore the metrology of these buildings offer notable changes in the elevation and plan. On the other hand, they are fixed with Portland cement and aggregate mortar with wide joints of 2cm, underlining the grey colour of them when the walls are not cladded with a cement rendering. They also use pillars of reinforced concrete to embrace the walls. The slabs are flat with cap domes of bricks and the simplest ones have galvanised brass roofs.

4. Incomplete sustainability

Considering that it is not a renewable source, even though there are no studies concerning the speed of exploitation of the quarries, one can question the sustainability of the stone masonry with this type of natural stone. This is not because of the use in restorations but because of the greater demand of this material for popular buildings. In favour of it, is the fact that it does not require any fuel for its exploitation as opposed to the greater energy consumption that the production of other materials such as bricks demand. One has to add that the concept of environmental sustainability is not easily applied where the production of new and economical materials is very slow.

Nevertheless, the restoration and rehabilitation are based on the principle of sustainability in conservation understood as the policy of respect to the built heritage in exchange to indiscriminate demolitions and substitutions of new buildings of less environmental value. Another aspect to consider is that the manual dismantling of the walls that will not be rebuilt allowing for the conservation of stone masonry. The same stones are recycled to erect other new wallings. From these points of view, the sustainability could be stressed, when in the future the exploitation of these quarries is reduced and if the remaining slag is reused.

CONCLUSIONS

The conservation of the architectural heritage is one of the main reasons for maintaining the traditional masonry using an inappropriate stone for seismic areas. The actions to extend the life of historical buildings and to recuperate their aesthetic values have particular features in a world-wide context. This is specially the case with materials with local use and if those actions are to be performed in developing countries.

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